Solar UV Dosimetry

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Abstract. UV sensitive polymer dosimeters are important tools in research to optimize UV exposures to humans and to reduce the impacts of UV on agricultural production. The erythemal exposures to humans and the effectiveness of UV protective strategies have been measured with polysulphone dosimeters. Polysulphone dosimeters have been employed with appropriate calibration to measure the previtamin D_3 effective UV and the UVB exposures to plant leaves. A dosimeter based on polyphenylene oxide has been found to have a dynamic range that is approximately four times longer than that of polysulphone and a dosimeter that is sensitive to the visible waveband has been developed to measure photosynthetically active radiation.

Introduction

Skin cancers and sun-related eye problems are a serious public health problem. On the beneficial side, exposures to UV are required for the human production of vitamin D. Furthermore, solar UV has the potential to impact on the growth of plants. In order to optimize the UV exposures to humans and to reduce the impacts of UV on agricultural production, research to improve the understanding of the solar UV environment is required. Solar UV dosimeters are an important tool in this research. This paper reports on the use of dosimeters in different environments.

Erythemal UV Dosimeter

One category of UV dosimeters that have been employed in UV research is polysulphone dosimeters. These dosimeters are fabricated at USQ from polysulphone in thin film form. The polysulphone in thin film form is produced by dissolving polysulphone pellets (Aldrich Chemical Co., Inc. Milwaukee WI 53233 USA) in chloroform and casting the solution on a polished glass slab. The dosimeter has an overall size of approximately 3 cm x 3 cm. The polysulphone undergoes UV induced photodegradation when exposed to UV wavelengths shorter than approximately 340 nm. This photodegradation is quantified by measuring the pre- and post-exposure optical absorbance at 330 nm in a spectrophotometer in order to determine the change in optical absorbance (ΔA_{330}). To reduce errors due to any possible minor variations in the polysulphone film over the size of the dosimeter, the absorbances for each dosimeter are measured at four different sites over the dosimeter.

The change in optical absorbance is calibrated to a UV radiometer or spectroradiometer to allow the use of the dosimeters for measuring erythemal UV exposures. This is undertaken by subjecting the dosimeters to a series of solar UV exposures on a horizontal plane next to the input optics of the spectroradiometer or radiometer while measuring the solar UV exposures. Due to the minor mismatch between the spectral response of polysulphone and the erythemal action spectrum, it is essential to calibrate the polysulphone to the source spectrum that they will be employed to measure. The dynamic range of polysulphone allows the measurement of solar erythemal UV over periods of approximately three to six hours at a sub-tropical site in summer. This corresponds to an erythemal exposure of approximately 10 to 20 MED (minimum erythemal dose).

Dosimetric Measurements of UV Protection

Polysulphone dosimeters have also been employed in the investigation of the UV protection provided by different UV minimisation strategies, for example tree shade, hats, cotton clothing, nylon stockings, shade cloth and shade structures. An example of dosimeters employed to measure the protection from erythemal UV under shade structures is provided in Figure 1.

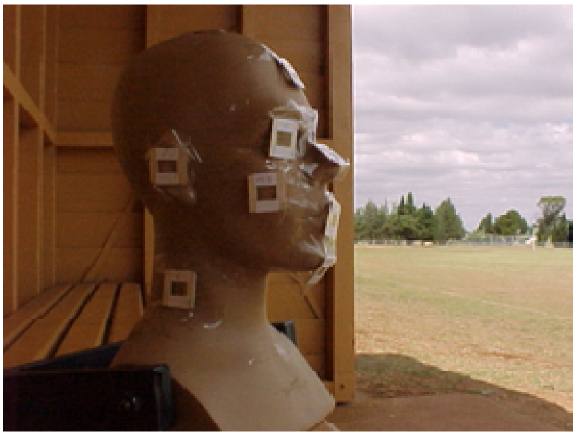

Figure 1. Dosimeters employed to measure the erythemal UV to specific facial sites under shade structures.

Photosynthetically Active Radiation Dosimeter

A new dosimeter has been reported for evaluating the photosynthetically active radiation (PAR). This dosimeter consists of 35 mm AGFA 25 APX photographic film with two pieces of pre-exposed film acting as neutral density filters [*Parisi et al,* 1998]. The dosimeter is 9 cm x 9 cm, with a total weight of 13 g and is fabricated from black plastic to prevent stray light leakage with an opening of 1 cm x 2 cm to expose the film. Following exposure, the film was processed with a standardised developing process and the change in absorbance at 800 nm, measured with a spectrophotometer and compared to a piece of processed unexposed film to quantify the amount of darkening of the dosimeter due to exposure.

The dosimeter was calibrated with a spectroradiometer recording the visible spectrum which allowed calculation of the photosynthetic flux density. The advantage of the dosimeter over conventional methods is that it is a passive system that requires no computer or other electronics or expensive equipment to measure the PAR at multiple sites simultaneously over a plant canopy. This cannot be achieved with conventional systems. Additionally, this dosimeter can be employed along with the polysulphone dosimeters to provide data on both PAR exposures and UV exposures. In terms of photosynthetically active photons, the dosimeter has a reasonable dynamic range and was calibrated for exposures between 0.003 and 0.38 mol m^{-2}.

UV Measurements on Plants

Research on the effects of UV radiation to plants during supplemental UV irradiation requires information on the UV exposures. Polysulphone dosimeters have been employed to measure the UVB (280-320 nm) radiation over a plant canopy [*Parisi et al,* 1998]. The supplemental UVB and the shading provided by the plant and the other plants changed the natural partitioning of UVB and PAR and the ratio of PAR to UVB exposures over the plant canopy. All these variations to the UVB and PAR over the plant canopy cannot be predicted by exposure measurements in the respective wavebands on a horizontal plane. Consequently, for the case of the complex topography of plants, measurements of the UV exposures with dosimeters have the advantage of allowing the exposures to be measured simultaneously at multiple sites that are at any orientation.

Long-term UV Dosimeters

The properties of polyphenylene oxide (PPO) cast as thin film of 40 μm thick have been investigated and found suitable [*Lester et al,* 2003] for use as a dosimeter to measure UV exposures that are higher than polysulphone can measure before saturation. The largest change in optical absorbance, as measured by a spectrophotometer, occurred at approximately 320 nm and this wavelength is recommended for the quantification of the amount of photodegradation. The dose response, spectral response, dose-rate independence, temperature independence between 1.5^o and 50^o and cosine error of less than 6.2% for angles of 40^0 or less indicate that PPO film can be used as a UV dosimeter. The spectral response of the PPO approximates the erythemal action spectrum between 300 and 340 nm. The dose response shows that a PPO dosimeter can measure erythemal UV exposures over approximately four summer days at a sub-tropical site before saturation. This is in comparison to polysulphone dosimeters that start to saturate with exposures of half a day to one day in summer at this latitude.

Dosimeters for Previtamin D_3

The solar UVB waveband acts as an initiator of the synthesis of vitamin D_3 for humans by the photolysis of 7-dehydrocholesterol in the human skin, to previtamin D_3. The action spectrum for the synthesis of previtamin D_3 shows that only wavelengths below 316 nm are effective [*Webb,* 1993]. This action spectrum can be approximated by the spectral response of polysulphone. Consequently, calibration of the dosimeters and employing the action spectrum for synthesis of previtamin D_3 allows measurement of the previtamin D_3 effective UV [*Parisi and Wilson*, 2005]. For the calibration, the dosimeters are subjected to a series of solar UV exposures on a horizontal plane while measuring the solar UV spectrum and the UV spectrum is weighted with the action spectrum for synthesis of previtamin D_3 [*Webb,* 1993].

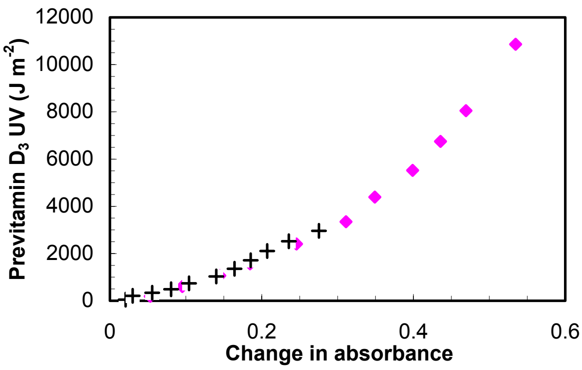

Figure 2. Calibration of polysulphone dosimeters to measure previtamin D_3 effective UV in winter (+) and summer (♦).

References

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